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ABSTRACT

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High School Mathematics Preparation and Sex Differences in Quantitative Abilities

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A sample of 2,093 students was randomly selected from all Washington State high school juniors taking a pre-college test battery in 1973. For the entire sample t tests indicated males took significantly more mathematics and scored higher than females on quantitative, spatial, and mechanical tests, while females had significantly higher mathematics grades. However, after controlling for type of mathematics coursework taken, sex differences disappeared on two of the four quantitative tests and on spatial ability.

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High School Mathematics Preparation and Sex Differences in Quantitative Abilities

Sex difference research is deeply indebted to Maccoby (1966; Maccoby & Jacklin, 1974) for succinctly organizing psychological research on a variety of sex difference topics. With respect to quantitative ability these investigators noted that, in general, there are no differences between boys and girls below age 14. However, sex differences subsequently emerge favoring males. Various explanatory factors have been offered including the greater tendency of males to enroll in mathematics and mathematics related courses in high school (HS) and later (Ernest, 1976; Remick & Miller, Note 1), more positive attitude of males towards mathematics (Aiken, 1970, 1976), greater anxiety of females towards mathematics termed "mathophobia" (Reese, 1961; Tobias, 1976), and a sex role stereotype endorsing the inappropriateness of mathematics for females coined the "feminine mathtique" by Osen (1974). The present paper focuses upon the first of these factors. If amount of study in mathematics and related courses were controlled, would males still be superior to females?

A review of citations given by Maccoby revealed only one study which attempted to control for prior coursework in mathematics. Hilton and Berglund (1974) controlled for total number of mathematics courses taken in grades 7-10, but not for specific mathematics courses. Examining the mathematics achievement of a group of students from grades 5 to 11, the authors also attempted to control for curriculum by dividing the samples into academic and non-academic groups. No sex differences were found at the 5th grade level but at subsequent grade levels (grades 7, 9, and 11) males had higher mean scores than females and these differences increased with age. This conclusion held for both the academic and non-academic groups.

In a more recent study, Fennema and Sherman (1977) controlled for mathematics preparation in a more precise manner by considering the specific courses taken, rather than a global summarization, and reported somewhat different findings. Subjects were students in four high schools currently enrolled in mathematics courses designated as "typical" for particular grades. Differences between the male and female groups in mathematics achievement and spatial visualization were significant in only two of the four schools and were very small where they existed. Additional support concerning the importance of controlling for relevant coursework came from analysis of covariance results. In one of the two schools in which the sexes differed significantly in mathematics achievement, they also

differed significantly in the number of "math related courses" (science courses) and when this was used as a covariate the sex difference became insignificant. Similarly, in both schools in which the sexes differed significantly on spatial visualization, they also differed significantly in number of "space related courses" (drafting, art) taken. When this variable was used as the covariate, the spatial ability sex difference disappeared.

Following the lead of Fennema and Sherman, the current study attempted to use a more refined procedure for examining sex differences in quantitative ability by grouping males and females according to their patterns of mathematics coursework rather than the simple number of semesters taken. It was hypothesized that when grouped according to coursework patterns sex differences in subsequent quantitative test scores would not emerge.

Other relevant variables were also studied. Spatial ability was included for two reasons: First, because of the similarity in sex difference findings in spatial and quantitative abilities, and second, because of the hypothesized relationship between mathematics preparation and spatial visualization reported in Fennema and Sherman (1977) where, for samples grouped according to the "typical" course for that grade level, significant sex differences emerged in only two of their four groups. Further, inasmuch as it is well documented that females have higher academic performance than males (Lavin, 1965), mathematics grade point average (GPA) was also included. Lastly, mechanical reasoning and physics, cognitive areas highly related to mathematics, were also included--mechanical reasoning to be analyzed along with the quantitative tests and physics in the coursework patterns.

Method

Test battery and HS transcript. The eight test scores (Washington Pre-College Testing Program or WPC, Note 2) studied were:

Quantitative Skills or QST - a score comprised of two subtests, QSA and QSB, assessing skills in handling data and in observing relationships between quantities

Applied Mathematics or AM - ability to solve applied mathematics and elementary algebra problems

Mathematics Achievement or MA - knowledge of algebra and geometry

Quantitative Composite or QC - a composite score of QST, AM, and MA

Spatial Ability or SA - ability to visualize transformations in three dimensions

Mechanical Reasoning or MR - ability to understand physical principles as applied to mechanical devices

All WPC scores are normed to a mean of 50 and a standard deviation of 10.

All students in this sample took the WPC battery during the second semester of their HS junior year. Each participant's transcript for grades 9-11 provided the grades and semester credits for mathematics coursework subdivided into general mathematics (GEN), algebra (ALG), geometry (GEO), and advanced mathematics (ADV). Vocational mathematics courses (e.g., accounting, business mathematics) are considered "electives" and were not considered in the current analysis.

Sample. By computer selection every tenth individual tested in spring 1973 was selected for the current study. The 200 juniors who had taken "fractional semesters" of mathematics or physice coursework were eliminated leaving a sample of 2,093 (962 males and 1,131 females).

Forming the coursework groups. For each sex separately students were grouped according to number of semesters of GEN, ALG, GEO, ADV, and physics (PHY) taken. There were eight patterns among the female group having 30 of more females. These 8 patterns accounted for 75% of the total female group. For the males there were six patterns having 30 or more students and these six accounted for 61% of the males. Five patterns accounted for 30 or more of each sex: (1) 2 semesters of ALG (male $N = 44$, female $N = 125$), (2) 2 semesters each of ALG and GEO (male $N = 167$, female $N = 330$), (3) 3 semesters of ALG and 2 semesters of GEO (male $N = 33$, female $N = 30$), (4) 4 semesters of ALG and 2 semesters of GEO (male $N = 206$, female $N = 182$), and (5) 2 semesters each of ALG, GEO, and ADV (male $N = 99$, female $N = 67$).

Statistical analyses. For the total groups of males vs. females, t tests were computed for the five coursework areas (GEN, ALG, GEO, ADV, and PHY), overall mathematics GPA (MATHGPA), and the eight WPC scores (QSA, QSB, QST, AM, MA, QC, SA, and MR). Next, between males and females in each of the five coursework groups t tests were computed for MATHGPA and the eight WPC scores. Lastly, multiple regression analyses were performed using the total sample predicting the test criteria from coursework areas alone, and from course areas plus sex (SEX). The inclusion of SEX as a predictor was tested for significance. For any criterion for which SEX was a significant predictor, mean actual and predicted scores (i.e., based on the regression equation for the criterion with only

coursework areas as predictors) were then compared for each sex separately. For those criteria in which SEX was a significant predictor the effect of controlling for mathematics achievement, in addition to controlling for coursework, was also explored. Thus, two more regression equations were computed, the first based upon coursework areas and MATHGPA and the second on coursework areas, MATHGPA, and SEX. Again, the inclusion of SEX as a predictor was tested for significance.

The statistical package employed (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975) included two different variance estimates for the *t* tests. When the variances were in fact homogeneous, the "pooled variance estimate" was used to calculate the standard error of the difference between the means and this was employed to calculate *t*. The "separate variance estimate" was used when there was heterogeniety of variance and yielded an approximation to *t*, tested for statistical significance using the modified degrees of freedom (*df*) provided by the statistical package. The *df*'s vary, therefore, depending upon the variance estimate employed.

Results

Table 1 presents the *t* tests contrasting the total groups of males and females which result in significant differences in four course areas and in all eight WPC scores at the .001 level favoring males. Only for MATHGPA was there a significant difference favoring the females ($p < .05$). Men take more mathematics courses and score higher on tests of quantitative ability while women earn higher grades.

But what happens when students are grouped into coursework patterns? For the group with only 2 semesters of ALG, there was a significant difference only for MR with the males having a mean of 51.57 and the females a mean of 42.14. For the second group (2 semesters each of ALG and GEO) there were two significant differences favoring females and two favoring males. Women had higher MATHGPA than men (2.66 vs. 2.32) and higher QSA (50.14 vs. 47.52), while the men had higher means on AM (50.40 vs. 47.57) and on MR (54.19 vs. 46.23). In the group with 3 semesters of ALG and 2 of GEO, the women obtained a significantly higher mean AMTHGPA than the men (2.69 vs. 2.18), while the men had a significantly higher MR mean (55.00 vs. 45.10). For the fourth pattern, 4 semesters of ALG and 2 of GEO, females had a significantly higher MATHGPA score (3.06 vs. 2.82) and males scored significantly higher on AM (54.92 vs. 52.80) and on MR (53.78 vs. 49.19). The largest number of significant differences, 6 in total, was noted in the coursework pattern representing 2 semesters each of

Table 1

Means of Total Groups on Semesters of Coursework, Mathematics GPA, and WPC Scores

Variables	Male (N=962)		Female (N=1,131)		Mean	t(df)
	M	SD	M	SD	difference	
Course areas (semesters taken)						
GEN	0.24	0.67	0.29	0.77	-0.05	-1.46(2071)
ALG	2.85	1.17	2.52	1.12	0.33	6.53(2073)***
GEO	1.62	0.78	1.42	0.91	0.20	5.51(2073)***
ADV	0.51	0.90	0.25	0.64	0.26	7.55(1685)***
PHY	0.16	0.55	0.04	0.27	0.12	5.88(1342)***
Math GPA, WPC scores						
MATHGPA	2.61	0.81	2.68	0.78	-0.07	-2.09(2068)*
QSA	51.12	10.48	49.13	9.72	1.99	4.48(1981)***
QSB	52.40	10.71	48.49	9.66	3.91	8.71(1955)***
QST	52.05	10.68	48.58	9.58	3.47	7.77(1950)***
AM	52.54	10.04	47.79	10.01	4.75	10.78(2091)***
MA	52.16	10.46	48.38	9.70	3.78	8.52(1980)***
QC	52.52	10.35	48.06	9.71	4.46	10.10(1990)***
SA	51.19	10.46	49.11	9.45	2.08	4.73(1957)***
MR	54.74	8.80	45.67	8.76	9.07	23.56(2091)***

Note. Variable designations: general mathematics (GEN), algebra (ALG), geometry (GEO), advanced mathematics (ADV), and physics (PHY). Overall mathematics GPA is MATHGPA and the WPC scores are: Quantitative Skills, A(QSA), Quantitative Skills, B(QSB), Quantitative Total (QST), Applied Mathematics (AM), Mathematics Achievement (MA), Quantitative Composite (QC), Spatial Ability (SA), and Mechanical Reasoning (MR).

*p <.05 ***p <.001

ALG, GEO, and ADV. A significant difference favoring females was obtained for MATHGPA (3.21 vs. 2.96). For males MR was once again superior (57.14 vs. 47.87). Males were also favored on QSB, QST, AM, and QC (58.57 vs. 56.12, 58.78 vs. 56.37, 56.98 vs. 53.45, and 59.02 vs. 56.19).

Four consistent findings should be noted. Only for Mechanical Reasoning was there a significant difference in all five groups favoring males. Secondly, women consistently had a higher MATHGPA (in four groups this difference was significant and in the fifth, the direction of the difference favored females). Thirdly, for all five groups there was no significant difference between males and females in either MA or SA. Finally, as the groups gained in mathematics training male performance on the quantitative tests became superior.

Turning now to the regression analyses presented in Table 2. To provide a more powerful test of the effect of high school coursework on test scores, using all members of the sample, the WPC test scores were predicted from the five course areas. These squared multiple correlations are presented in Table 2 under the column labeled "R^2_C". When SEX was included among the predictors and the increment in R^2 tested for significance, SEX did not increase the predictability of half of the criteria (i.e., QSA, QST, MA, and SA). For the remaining 4 WPC criteria (QSB, AM, QC, and MR) where SEX was a significant predictor, a comparison was made between the predicted mean score (based on the formula derived for the total group and used to compute R^2_C) and the actual mean score for each criterion for the sexes separately. In all four instances, the women's means were overpredicted and the men's underpredicted based on the regression equations for the total sample. Next, for these 4 criteria a second set of regression analyses was computed--this time including MATHGPA along with the course areas as the basic predictors (R^2_{C+M} in Table 2) and testing for the addition of SEX to these 6 predictors. As Table 2 indicates, the addition of SEX was highly significant for all 4 test criteria. And, using the basic prediction equations from R^2_{C+M}, the women's means were again over- and the men's underpredicted.

Thus, using the statistically more powerful multiple regression analyses, several of the t-test results were supported. First, both types of data analyses indicated that by controlling for amount of mathematics preparation the sexes don't differ in their degree of predictability for MA and SA. Secondly, MR was again influenced by sex regardless of the control exercised over preparation in mathematics. In the regression analyses the sex effect was the largest for MR where the

Table 2

Multiple Regression Analyses of WPC Test Criteria Examining Sex as a Predictor

(Decimal points omitted)

Criterion	R^2_C	R^2_{C+SEX}	$F(1,2063)$	R^2_{C+M}	$R^2_{C+M+SEX}$	$F(1,2062)$
QSA	290	291	.975	--	--	--
QSB	414	416	8.251***	533	546	59.156***
QST	425	425	2.624	--	--	--
AM	266	281	44.203***	346	379	107.286***
MA	509	510	2.602	--	--	--
QC	446	452	20.030***	565	585	96.325***
SA	107	108	2.729	--	--	--
MR	156	293	419.968***	168	333	509.103***

Note. R^2 subscripts denote predictors: C = course areas (GEN, ALG, GEO, ADV, PHY), SEX = SEX, M = MATHGPA. In all instances for which sex was a significant predictor, R^2_C (or R^2_{C+M}) overpredicted the female scores and underpredicted the male.

*** $p < .005$

squared multiple correlation using SEX and the course areas as predictors was nearly double that computed from the course areas alone. Similarly, in the t-test analyses MR was the only criteria which significantly favored the males whether the sexes were treated as a whole or broken down into coursework patterns. In addition, these results seem to suggest that QST, and one of its subtests QSA, were also uninfluenced by sex once prior mathematics preparation was controlled for. The t-test results supported this conclusion where four of the five patterns studied reported no significant differences between the sexes on these two tests. Lastly, it is of interest to note the complex nature of MATHGPA. In the statistically simpler analyses, t tests indicated that MATHGPA was a variable which favored the females whether taken as a whole or subgrouped into coursework patterns. However, when included as a predictor along with the course areas for the four WPC criteria (QSB, AM, QC, and MR) for which SEX significantly increased the proportion of criterion variance accounted for above that accounted for by the course areas alone, the significance of SEX as a predictor still remained. And in both sets of regression analyses for these 4 criteria, using the regression equations based on the total sample the women's means were overpredicted and the men's underpredicted.

Discussion

These results suggest that sex differences in quantitative ability and spatial ability are partially reflections of differential mathematics training, as had been hypothesized based upon the research of Fennema and Sherman (1977). In Table 1 the sexes differed significantly with respect to the amount of algebra, geometry, advanced mathematics, and physics taken and on all 6 quantitative, the spatial ability, and the mechanical reasoning WPC scores with the males having taken more coursework and having higher test scores. Only for MATHGPA did the women have a significantly higher mean than the men. However, when males and females were grouped according to coursework preparation, t-test results showed that sex differences declined appreciably in five quantitative areas (QSA, QSB, QST, AM, and QC) and disappeared on MA and SA. Only for MATHGPA and MR were the sex differences unaffected. Inasmuch as MA measures knowledge of algebra and geometry, it is not surprising the matching groups on amount of algebra and geometry eliminated the difference. This does not explain why spatial ability likewise is no longer different in the sexes.

Using the regression analyses, which allowed for the use of the total sample and the full range of course patterns, strong support was garnered for the two main t-test results. Once again, MA and SA were unaffected by sex after coursework preparation was controlled for, and, secondly, the MR test once again exhibited the strongest sex effect. In addition to supporting these two t-test results, the regression analyses reported that QSA, also, was unaffected by sex since the addition of sex as a predictor did not significantly increase the proportion of criterion variance accounted for above that due to the course areas alone. A re-examination of the t-test results revealed that for only one pattern out of five did the sexes differ significantly on QSA and that difference favored the women. The inclusion of sex as a predictor of QST did not increase this criterion's predictability but the absence of a "sex effect" is presumably due to QSA, however, and cannot be considered a unique result. Thus, the more powerful regression analyses suggest that controlling for prior amount of mathematics coursework would eliminate the importance of sex as a predictor for half of the quantitative tests (i.e., MA and QSA) and SA but not for QSB, AM, and MR.

Why might certain quantitative differences--MA and QSA--disappear while others, namely QSB and AM, do not? One can speculate and suggest several reasons why this might occur, the three most important being sex bias in item content, lack of exercising adequate control for relevant coursework, and not controlling for quantitative aptitude assessed prior to entry to high school.

The first explanation for these sex differences concerns the possible existence of sex bias in item content. Several studies (Graf & Riddell, 1972; Hoffman & Maier, 1966; Milton, 1959) have shown that problem content does tend to influence sex differences in problem-solving ability--difference between the scores of men and women were reduced when the problems were stated with "feminine" content. Thus, the sex differences appearing in QSB and AM might be due to relatively large proportions of "male-oriented" items. Obviously, item analyses are necessary to explore this possibility.

Another possible explanation concerns the lack of appropriate control of relevant coursework. Recall that AM is the WPC subtest which assesses students' ability to solve applied mathematics and elementary algebra problems. Therefore, besides subdividing mathematics coursework into GEN, ALG, GEO, and ADV, an additional subgroup comprised of various applied mathematics courses (such as technical drawing, woodworking, electronics) might be advisable prior to testing AM for possible sex

differences. This explanation does not seem adequate for QSB, however, since QSA and QSB are both subtests which assess the same skills (i.e., handling data and observing relationships between quantities) and one would therefore expect both subtests to be equally influenced, or uninfluenced, by the same coursework controls.

The third likely candidate "causing" the sex differences to appear on QSB and AM might be the neglect of controlling for quantitative aptitude as measured, for example, by a standard junior high school test battery. Surprisingly, the control of earlier quantitative ability in studies of sex differences in quantitative achievement has been seemingly neglected, and yet the relationship between aptitude and achievement has been well-documented (Lavin, 1965). For instance, one study (Hoffman & Maier, 1966) reported that although men students solved more of the masculine versions of 8 reasoning problems than the women did, when mathematical aptitude was held constant there were no sex differences. Therefore, the question posed here is, if ability level was held constant would sex differences on QSB and AM still emerge?

It is obvious that the various components which influence performance on tests of quantitative ability cannot be treated as separate, unrelated entities. Specifically, what is the relationship between aptitude and the selection of HS mathematics courses? Does the dwindling sex difference in quantitative abilities in the current study merely reflect the effect of coursework preparation in mathematics or do the more quantitatively able simply take more math courses during their first three years of HS? Returning to the 5 coursework patterns examined in the t-test analyses above, it was noted that for those patterns representing larger amounts of mathematics training there was an indication of superior male performance on the quantitative tests. At first glance this seemed contrary to what one might expect. However, if one considers that these patterns are all considered to fulfill the minimum, standard college entrance requirement for HS mathematics (that is, at least 2 full years of college preparatory math), then one might surmise that these patterns are comprised of students having varying levels of quantitative aptitude. With this possibility in mind, therefore, the t-test results make more " sense." It would seem imperative, therefore, that future studies concerning sex differences in quantitative ability include mathematical aptitude along with coursework preparation in mathematics, not only to assess their effect upon quantitative test scores but also to examine the interaction of these two very critical variables upon sex differences in quantitative abilities.

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